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The Effect of a Progressive Resistance and Flexibility Exercise Program on Free Running Speed

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THE EFFECT OF A PROGRESSIVE RESISTANCE AND FLEXIBILITY EXERCISE PROGRAM ON FREE RUNNING SPEED

BY

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This thesis is approved as a creditable, independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree; but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser

Head of the Major Department

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CHAPTER I

INTRODUCTION

The speed of an athlete has always been of great importance to the athletic coach and suggested methods of improving speed have resulted in many studies in research. In 1957, Meisel found that even though an 18 session progressive resistance program did increase leg strength, it significantly reduced the free running speed.[1] This was contrary to results of previous research which indicated increased leg strength did improve running speed.

There exists the theory that the stronger the legs, the more capable the runner is of overcoming the resistance of body weight, and therefore the whole body should be propelled at a faster speed. Carnes has stated, "By increasing his leg power, a boy can increase his speed."[2] Through their experience with football players, George and Evans stated that football players are able to run faster after training with weights or through a progressive resistance program.[3]

The author felt that the more flexible the joints, the greater efficiency the muscles in executing body movements. Increased flexibility is an increase in the maximum range of movement in a joint.

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[1]Stephen G. Meisel, The Effect of a Weight Training Program on the Speed of Running, Unpublished Master of Science Thesis, Pennsylvania State University, University Park, Pennsylvania, 1957.

[2]Jimmy Carnes, "Weight Training for Track", Scholastic Coach, vol. 30:6, p. 34, February, 1961.

[3]Elvan George and Ralph Evans, Weight Training for Football, p. 147, Prentice-Hall, Inc.; Englewood Cliffs, New Jersey, 1959.

Greater flexibility in the hip joints should lead to an increased stride and this means a greater distance can be covered with the same amount of muscular effort. If this is correct, greater flexibility of the hip joints should enable the leg muscles to propel the body more efficiently, and possibly faster.

Delimitations

1. This study was limited to freshman men at South Dakota State College in the required service program. Men out for winter track were not considered in the study, as they were in running activities.

2. The experimental group was a "captive" group, and did not volunteer for the study.

3. The training program lasted 6 ½ weeks or 13 training periods.

4. The method used in testing leg strength was without the belt in the leg dynamometer strength test.

5. Neither group had received instruction concerning correct mechanical running form.

6. The test of speed was over a distance of 20 yards.

7. The test of speed was "triggered" for start and stop by foot contact, which may have had an effect on the free running speed.

Significance

Much has been written supporting the use of progressive resistance exercises for the development of athletic ability. Prior to Meisel's study, experiments indicated that running speed did improve with weight training. Therefore, further studies of a similar nature

may confirm or reverse the findings.

The present study added two new factors. The training program included exercises designed to improve the flexibility of the hip joint in order to increase the stride, and added a weight lift designed to strengthen the quadriceps muscle group. To the author's knowledge, this is the first study to consider the relation of hip flexibility to running speed.

Definitions

1. Progressive resistance exercises and weight training both refer to lifting of weights by means of barbells and dumbbells, and adding more weight, or resistance, as the individual's strength becomes greater.

2. Flexibility refers to the range of movement of body segments at joints.[4]

3. The required service program is a one year physical activity program required of all freshmen at South Dakota State College.

4. The training program refers to those progressive resistance and flexibility exercises used in this study.

5. Free running speed refers to maximum running speed. This is in contrast to measuring speed from a stationary start which includes the factors of explosive force out of the blocks and rate of pick up to full speed.

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[4]Jack R. Leighton, "On the Significance of Flexibility for Physical Educators", Journal of Health, Physical Education, and Recreation, vol. 31:8, p. 27, AAHPER: Washington, D. C., November, 1960.

CHAPTER II

REVIEW OF LITERATURE

There exists a vast quantity of literature relating to weight training and athletic ability, but little has been written concerning flexibility and athletic ability. This review is confined to literature relating to the effect of weight training on leg strength, leg strength to running speed, effect of weight training on speed of movement, of weight training on flexibility, of exercise on flexibility, and the relation of flexibility to speed of movement.

Effect of Weight Training on Leg Strength

Capen conducted a study of sophomore men at the University of Tennessee in which he compared the effects of a nine week weight training program and a nine week strenuous conditioning course on power, endurance, and strength. Part of the strength test included the measurement of leg strength by the back and leg dynamometer using the belt method. He found that the leg lift improved 34.8 per cent over the original test, which was significant to the .02 level. The improvement of the weight training group was 21.1 per cent greater than the improvement of the conditioning course group as measured by leg strength.[5]

Black studied the effect of a seven month weight training program on 50 high school boys as measured by the Roger's Physical Fitness Index.

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[5]Edward K. Capen, "Effect of Systematic Weight Training on Power, Strength, and Endurance", Research Quarterly, vol. 21:2, pp. 83-93, AAHPER: Washington, D. C., May, 1950.

It was found that the weight training program increased the test scores significant to the .01 level. A portion of the Roger's Test is the leg lift as measured by the back and leg dynamometer using the belt. The weight training group improved 22.4 per cent over the control group in this test.[6]

More recently, Brown and Riley studied the effect of weight training on leg strength and the verticle jump, using 40 freshman basketball candidates at Springfield College. Twenty men participated in a five week, three day per week, weight training program, and the remaining 20 served as the control group. Leg strength was measured before and after the program by the back and leg dynamometer with the belt. The mean increase of the experimental group was 161 pounds, which was significant beyond the .01 level.[7]

Leg Strength and Speed

Bannister, the first man to run the mile under four minutes, has stated, "Maximal contractile activity of the muscle limits speed in sprinting." He also stated that increasing the contractile activity should increase this limit.[8]

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[6]Irving S. Black Jr., The Effect of Weight Training on Physical Fitness Index of High School Boys, Unpublished Master of Education Thesis, Boston University, Boston, Massachusetts, 1952.

[7]R. J. Brown and D. R. Riley, "Effect of Weight Training on Leg Strength and Verticle Jump", Scholastic Coach, vol. 27:4, pp. 44-47, December, 1957.

[8]Roger Bannister, M.D., "Muscular Effort", British Medical Bulletin, vol. 12:3, pp. 222-225, September, 1956.

Ostrander studied the relationship of extensor strength in the legs of elementary boys to performance in the standing broad jump and the 30 yard dash. The study included 114 boys ranging from 6 ½ to 12 ½ years of age. The relationship of total extensor strength to performance in the dash was significant at the .02 level for only 11 year old boys.[9]

Weight Training and Speed

Zorbas and Karpovich tested 300 known weight lifters and 300 non-lifters in speed of arm movement. The instrument used measured rotary arm action. They found that weight lifters had quicker rotary arm action than non-lifters. The difference was significant to the .01 level.[10]

Wilken studied the effect of weight training as compared to activity in swimming and golf, on the speed of arm movement as measured by turning an instrument similar to a bicycle crank. He used an experimental group of men taking one semester of weight training, but with no past weight training experience, another experimental group of members of the University of California weight lifting team, and a control group of non-lifters in swimming and golf classes. He found that one semester

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[9]Elijah Ostrander Jr., A Study of the Relationship Between Extensor Strength of the Muscles of the Lower Extremities, and Performance Scores in the Standing Broad Jump and the Thirty Yard Dash of Elementary School Boys, Unpublished Master of Science Thesis, University of Wisconsin, Madison, Wisconsin, 1955.

[10]William S. Zorbas and Peter V. Karpovich, "The Effect of Weight Lifting Upon the Speed of Muscular Contraction", Research Quarterly, vol. 22:2, pp. 145-148, AAHPER: Washington, D. C., May, 1951.

of weight training does not increase speed of movement more than a semester of beginning swimming or golf. He indicated that weight training has no slowing effect on speed of arm movement, that the speed of experienced lifters is as great as the other studied, and experienced lifters improve as much in speed during a semester as the other groups studied.[11]

Masley, Hairabedian, and Donaldson studied freshman and sophomore men at Pennsylvania State College to determine the effects of training on strength, speed, and coordination. The study included an experimental group taking six weeks of beginning weight training, and two control groups in a volleyball class, and a sports lecture class. The weight training group increased in speed, as measured by rotary arm movement, and strength more than a similar period of volleyball or inactivity.[12]

Swegan tested two groups of 30 college men, who participated in either a progressive resistance weight training program or a static contraction program, on speed of eight different movements. The tests were given prior to and at the completion of the programs. Speed of movement in the weight training group was significantly slowed in six of the eight movements. The remaining two movements also slowed, but

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[11]Bruce M. Wilken, "The Effect of Weight Training on Speed of Movement", Research Quarterly, vol. 23:4, pp. 361-369, AAHPER: Washington, D. C., December, 1952.

[12]John W. Masley, Ara Hairabedian, and D. N. Donaldson, "Weight Training in Relation to Strength, Speed, and Co-ordination", Research Quarterly, vol. 24:3, pp. 308-315, AAHPER: Washington, D. C., October, 1953.

the change was not significant at the .05 level.[13]

Yankosky studied the effect of weight training on arm and leg extension and flexion speeds. The experimental group was in a weight training program for 11 weeks. The movement speed of all four tests was slightly improved by the weight training group. The control group changed very little. There was no statistically significant change in either group.[14]

Chui investigated the effect of a three month weight training program on several athletic tests, including a 60 yard dash. Of the 22 subjects in the weight training group, 17 showed an improvement in running speed averaging .33 second. Of the remaining five, four showed no change, and one ran slower by .1 second. Chui felt these results indicated the probability of increasing speed through training with systematic weight training exercises.[15]

Meisel conducted a study in 1957, in which he found the effect of an eight week weight training session on the free running speed of college men. The experimental group consisted of 52 men in weight training classes, while the control group consisted of a like number from a

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[13]Donald B. Swegan, The Comparison of Static Contraction with Standard Weight Training in Effect on Certain Movement Speeds and Endurance, Unpublished Doctor of Education Thesis, Pennsylvania State University, University Park, Pennsylvania, 1957.

[14]Eugene Yankosky, The Effect of Weight Training on Speed of Movement, Unpublished Master of Science Thesis, Pennsylvania State University, University Park, Pennsylvania, 1958.

[15]Edward Chui, "Effect of Systematic Weight Training on Athletic Power", Research Quarterly, vol. 21:3, pp. 188-194, AAHPER: Washington, D. C., October, 1950.

non-activity sports lecture class. They were all tested at the beginning of the eight week period for leg strength, as measured by the back and leg dynamometer with the belt, and for free running speed at a distance of 10 yards by a chronometer. Measurement was to the nearest .01 second. The groups were paired on the basis of the preliminary speed of running test. The lifts executed by the experimental group included arm curls, shoulder press, toe raises, full squats, right and left knee flexion, with a metal boot, and right and left gluteous pull with a metal boot. The latter lift was executed by lying prone and lifting the weighted leg while keeping it straight. The subjects were re-tested at the end of the training period. It was found that progressive weight resistance exercises significantly increase the strength of the legs, but caused a loss of speed in running a distance of 10 yards at maximum speed. The mean loss in speed was .0108 second, and was significant to the .02 level of confidence.[16]

Weight Training and Flexibility

An investigation was undertaken, by Massey and Chaudet, to study the effects of systematic, heavy resistive exercise on the range of joint movement in young, male adults. Two groups of 13 men, experimental and control, were employed. The experimental group trained with weights for 6 ½ months, while the control group participated in other kinds of physical activity. Measures in range of joint movement were taken prior

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[16]Stephen G. Meisel, The Effect of a Weight Training Program on the Speed of Running, Unpublished Master of Science Thesis, Pennsylvania State University, University Park, Pennsylvania, 1957.

to training, midway through the training period, and at the end of training. It was found that participation in the program did not result in an overall reduction in range of movement of joints throughout the body. Hip flexion tended to increase or show less decrement in the weight training group as opposed to the control group. The mean difference in hip flexion was a gain of 1.5 degrees.[17]

Flexibility Exercises and Greater Flexibility

In a recent article, Leighton stated he believed flexibility can be altered through activity. He reported on the Kraus-Hirschland study showing that all athletic groups displayed much greater hip flexion and extension than the average sixteen year old boy.[18] Cureton has suggested that flexibility exercises may condition muscles, tendons, ligaments, and bones to greater elasticity and tensil strength.[19]

Riddle compared the spring-stretch, held-stretch, and combination-stretch methods of improving flexibility on 252 freshman women at the University of Oregon. Measurements were made of hip joint flexibility, and trunk-hip flexibility at the beginning of the exercise sessions and

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[17]Benjamin H. Massey and Norman L. Chaudet, "Effects of Systematic, Heavy Resistive Exercise on Range of Joint Movement in Young Male Adults", Research Quarterly, vol. 27:1, pp. 41-51, AAHPER: Washington, D. C., March, 1956.

[18]Jack R. Leighton, "On the Significance of Flexibility for Physical Educators", Journal of Health, Physical Education, and Recreation, vol. 31:8, pp. 27-28, AAHPER: Washington, D. C., November, 1960.

[19]Thomas K. Cureton, "Flexibility as an Aspect of Physical Fitness", Research Quarterly Supplement, vol. 12, AAHPER: Washington, D. C., 1941.

again at the end. All methods showed improvement in both measures. Increased flexibility of the hip joint was maintained longer without exercise than in the trunk.[20]

Villa studied 113 women concerning the effect of nine weeks of jumping exercises on knee and ankle flexibility. Both control and experimental groups decreased slightly in knee flexibility and increased in ankle flexibility as a result of the jumping exercises. It was indicated that jumping exercises do not necessarily influence the flexibility of knee and ankle joints.[21]

McCue determined the relationships of flexibility in 12 areas to amount of activity, body weight, knee injury, skill in the broad jump, and skill in an obstacle course, in 130 college women. Flexibility measurements were taken, a questionnaire was given, and the scores of the broad jump and obstacle course were recorded from the student's record cards. In comparing a more active and less active group, it was found that those individuals who had a past history of more activity tended to be more flexible. Mild exercise for a period of three weeks brought about a significant increase in flexibility for the lower

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[20]Kathryn S. Riddle, A Comparison of Three Methods for Increasing Flexibility of the Trunk and Hip Joints, Unpublished Doctor of Education Thesis, University of Oregon, Eugene, Oregon, 1956.

[21]Cynthia A. Villa, A Study of the Effects of Jumping Exercises on the Development of the Strength and Flexibility of the Knees and Ankles, Unpublished Doctor of Philosophy Thesis, University of Oregon, Eugene, Oregon, 1958.

quartile flexibility group.[22]

The effect of tumbling on flexibility was determined by Kingsley. A group of 28 high school freshman boys participated in a tumbling program five days a week for 20 weeks. Thirty flexibility measures were taken before and after this period. A significant increase was shown in 18 of the measurements. Only two measurements decreased significantly.[23]

Flexibility and Speed

Leighton felt that there is evidence that in order to develop skills to a high degree, a proper flexibility pattern for that skill must first be developed. Physical educators have been aware that flexibility is an asset to good performance in athletics, especially track. He warned that increased flexibility may decrease skills in some areas, including track.[24] McCloy has stated flexibility aids in a higher degree of competence in performance of activities.[25]

An investigation of the relationship of flexibility to general motor ability, as measured by the Scott Motor Ability Battery, was made by Olsen on 73 freshman women at the University of Oregon. The results

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[22]Betty F. McCue, "Flexibility Measurements of College Women", Research Quarterly, vol. 24:3, pp. 316-324, AAHPER: Washington, D. C., October, 1953.

[23]Donald B. Kingsley, Flexibility Changes Resulting from Participation in Tumbling, Unpublished Master of Science Thesis, University of Oregon, Eugene, Oregon, 1952.

[24]Leighton, loc. cit.

[25]Charles H. McCloy, Philosophical Bases for Physical Education, p. 69, F. S. Crofts and Company: New York, New York, 1947.

showed there was little or no significance in the relationship of the flexibility area measured to the Scott Motor Ability Battery. It was suggested that flexibility of the knees may be a factor in jumping, running, and body manuverability.[26]

McCue, in her study of the flexibility of college women, indicated that those who were in the upper quartile in the broad jump and obstacle race had a greater mean flexibility score in hip and hip-trunk flexion than the lower quartile group in the broad jump and obstacle race.[27]

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[26]Barbara H. Olsen, An Investigation of the Relationship of Ankle, Knee, Trunk, and Shoulder Flexibility to General Motor Ability, Unpublished Master of Science Thesis, University of Oregon, Eugene, Oregon, 1956.

[27]McCue, loc. cit.

CHAPTER III

PROCEDURES

The purpose of this study was to determine the effect of a combination progressive resistance and flexibility exercise program on free running speed. Tests determining leg strength, hip flexibility, and free running speed were administered to the experimental and control groups before and after a 6 ½ week program.

Selection of Subjects

Subjects used in this study were freshman men at South Dakota State College in the required physical education service program. An experimental group was composed originally of 43 subjects, who had chosen weight training as their required activity for the winter quarter. Members of the track team were excluded from the study. The control group of 42 men was chosen from two classes of volleyball and basketball. Again, members of the track team were excluded. Injuries and illness reduced the experimental group to 35 by the end of the training period. Five members of the control group failed to appear for one or more of the final tests, and two were dropped from the study in order to equate the groups in all of the preliminary tests according to mean and standard deviation. In the final analysis, both groups consisted of 35 subjects.

The subjects in the experimental weight training group were instructed not to engage in any form of weight training or flexibility

exercises outside of the class meetings, or to practice running. The control group was instructed not to engage in any form of weight training or to practice running for the duration of the experiment.

Test Apparatus and Methods

Three tests were administered before and after the experiment. All subjects were given a short preliminary warm-up in order to prevent injury and the same warm-up was administered at the beginning of each testing period.

Leg strength test. The Medart-Chatillon back and leg dynamometer was used to determine leg strength. The belt attachment was not used because of the time available for testing. The non-belt method is more reliable than the belt method in relation to the added factor of a backward lunge, but less reliable in relation to the ability to hold the handle in a fixed position.[28] Each subject was given two trials with the best trial being recorded to the nearest five pounds. If there was a large discrepancy between the two trials, a third trial was given, and the highest of the two close scores was recorded. This test was administered by the two instructors of the control groups. Care was taken to insure that each subject was tested by the same instructor for the initial and final test.

Hip flexibility test. The range of movement of the right hip in

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[28]Alfred W. Hubbard and Donald K. Matthews, "Leg Lift Strength: A Comparison of Measurement Methods", Research Quarterly, vol. 24:1, pp. 33-43, AAHPER: Washington, D. C., March, 1953.

flexion was determined by means of the Leighton flexometer.[29] The method used by Massey and Chaudet to determine hip flexion with the knee bent was used.[30] Two measurements were taken to the nearest degree and the average of the two readings was recorded. When both readings showed a marked discrepancy, a third reading was obtained and the average of the two close readings was recorded. All flexibility tests were administered by the author.

Speed of running test. (Figure 1). The test was administered over a 20 yards distance. The Hale performance timer was used to get performance time. A 40 yard rubber mat runway was used on the gymnasium floor. Two switch mats were placed on the runway at the 20 and 40 yard marks and secured to the running surface by means of adhesive tape. The performance clock started as a foot came in contact with the first mat, and stopped when a foot came in contact with the second mat. This often necessitated altering the stride in order to make contact with the mats.

Each subject was allowed one trial run to become adjusted to the placing of the mats. He wore rubber soled tennis shoes and a physical education costume consisting of a T-shirt and shorts. The subject was instructed to run the distance at maximum speed. He began his run 20 yards before the first mat, and was timed over the second 20 yards. There remained about 25 yards in the gymnasium in order to slow down.

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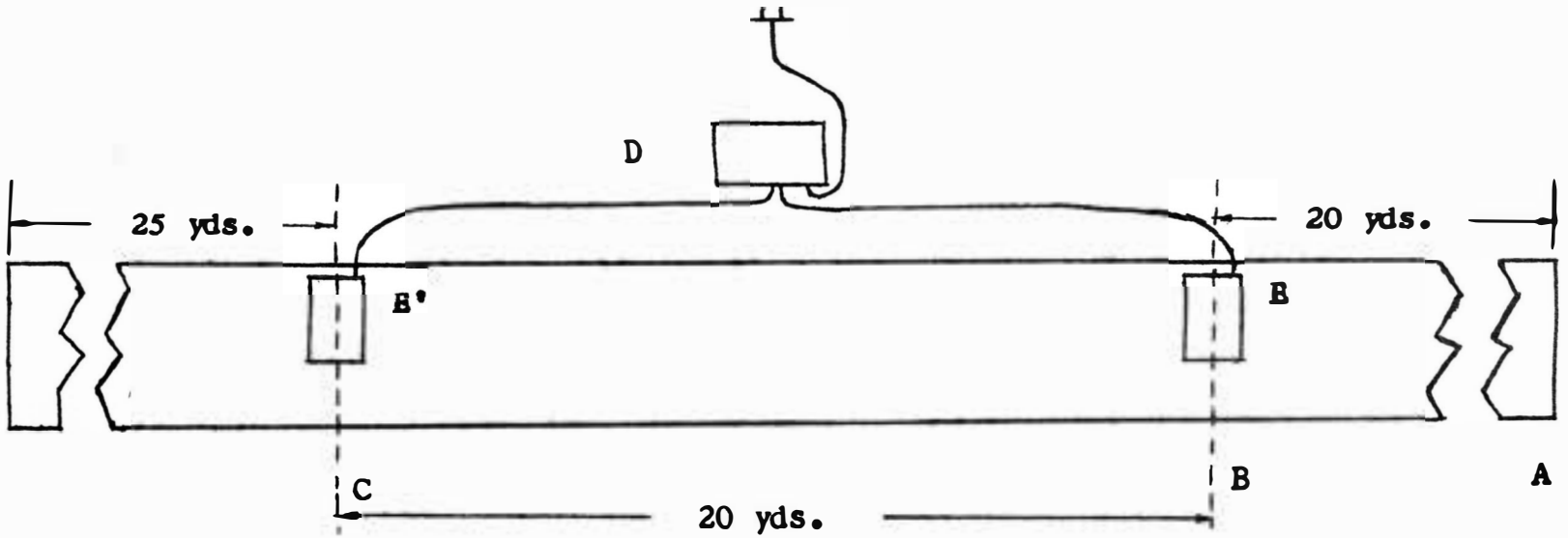
[29]Jack R. Leighton, "A Simple, Objective and Reliable Measure of Flexibility", Research Quarterly, vol. 13:2, pp. 205-216, AAHPER: Washington, D. C., M_, 1942.

[30]Massey and Chaudet, loc. cit.



A - Starting line

B - Beginning of timed run

C - End of timed run

D - Hale reaction timer

E - Switch mat

E'- Switch mat

Figure 1. Speed of Running Test Apparatus

Each subject was given a minimum of two trials at each testing and the fastest trial was recorded to the nearest .01 second. If a subject felt he had slipped or could run faster, he was allowed up to a maximum of four trials. The author administered all speed of running tests. A further explanation of all testing procedures is found in Appendix A.

Experimental Program

The experimental group was divided into two classes, both supervised by the author. They participated in a progressive resistance program of five lifts, which placed emphasis on the lower extremities, and a three exercise flexibility program, which also emphasized the lower extremities. The program lasted 6 ½ weeks or for 13 training sessions from January 19 to March 2, 1961. All absences were made up by attending a similar session under the supervision of the author. In order to complete the entire program at each session, the exercises were performed at five different stations, and each class was divided into five equal working groups of similar ability.

Progressive resistance program. The progressive resistance program consisted of five lifts, of which two were intended to develop the arms and shoulders, and three designed to strengthen the muscles used in running.

The shoulder press and the arm curl were included to strengthen the upper body. Carnes stated, "Since the arms always coordinate with the legs, it's important to stress this phase of the weight workout--making the upper body strong enough to move in coordination with the

lower body."[31]

Semi-squat walks (Figure 2) were used to give general development to the muscles of the lower extremities. The boot lift (Figure 3) necessitated the use of a metal boot and was designed to increase the power of the muscles used in flexing the hip. The toe rise exercise (Figure 5) was used to develop the gastrocnemeous muscles, used in extending the ankle.

Flexibility exercises. Two of the three flexibility exercises were performed with the use of barbells and all were designed to stretch the muscles and tendons near the hip and knee joints. The heel drop (Figure 4) was performed at the same time as the toe rise exercise. The toe board was 4 inches high, and the subject returned his heels all the way to the ground after each rise. With the added weight on the shoulders, this action exerted a strong pull on both the hamstring and the gastroc areas. The dead weight bounce (Figure 6) was performed by holding a barbell at arm's length and bending down as if to touch the toes. A bouncing motion was initiated with the subject attempting to reach lower each time, thus exerting a pull on the hamstring group. The final exercise was performed by the class as a group at the beginning of each class period. The "back bender" exerted stretching pressure on the muscles surrounding the knee and the quadriceps group (Figure 7).

More complete explanations on all the exercises in the experimental program, the amount of weight used, and number of repetitions are found in Appendix B.

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[31]Carnes, op. cit. p. 35.

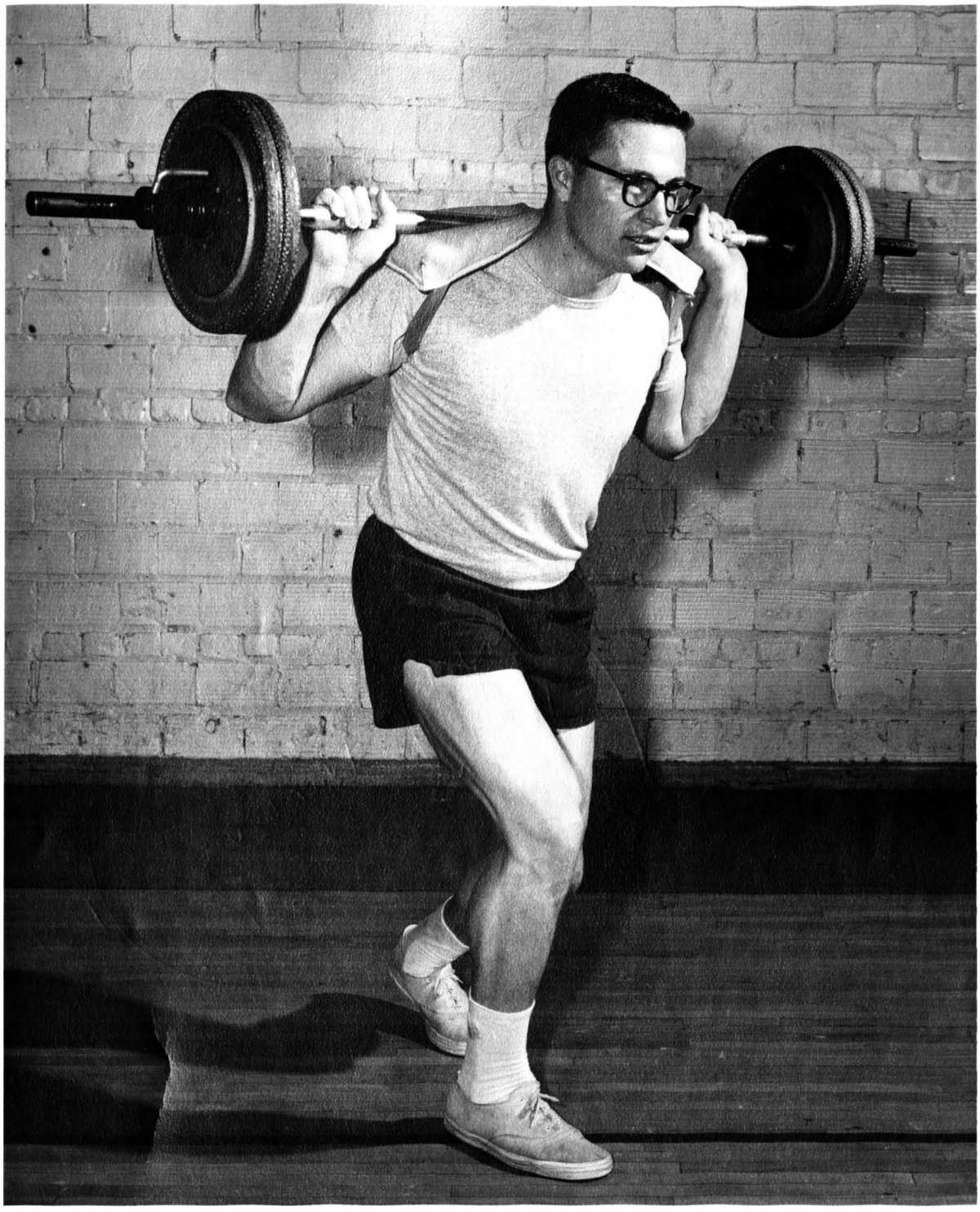

Figure 2. Semi-squat Walk

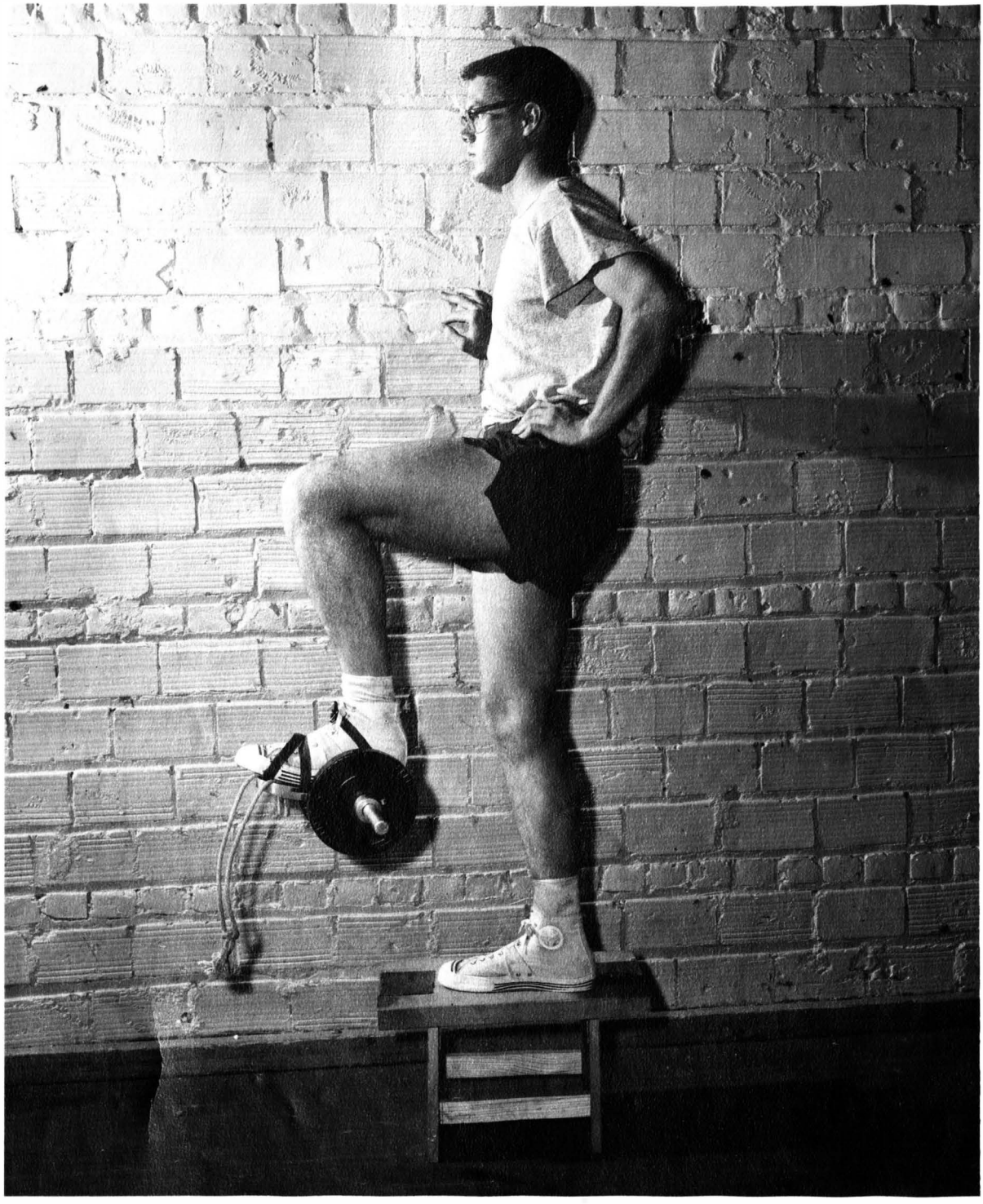

Figure 3. Boot Lift

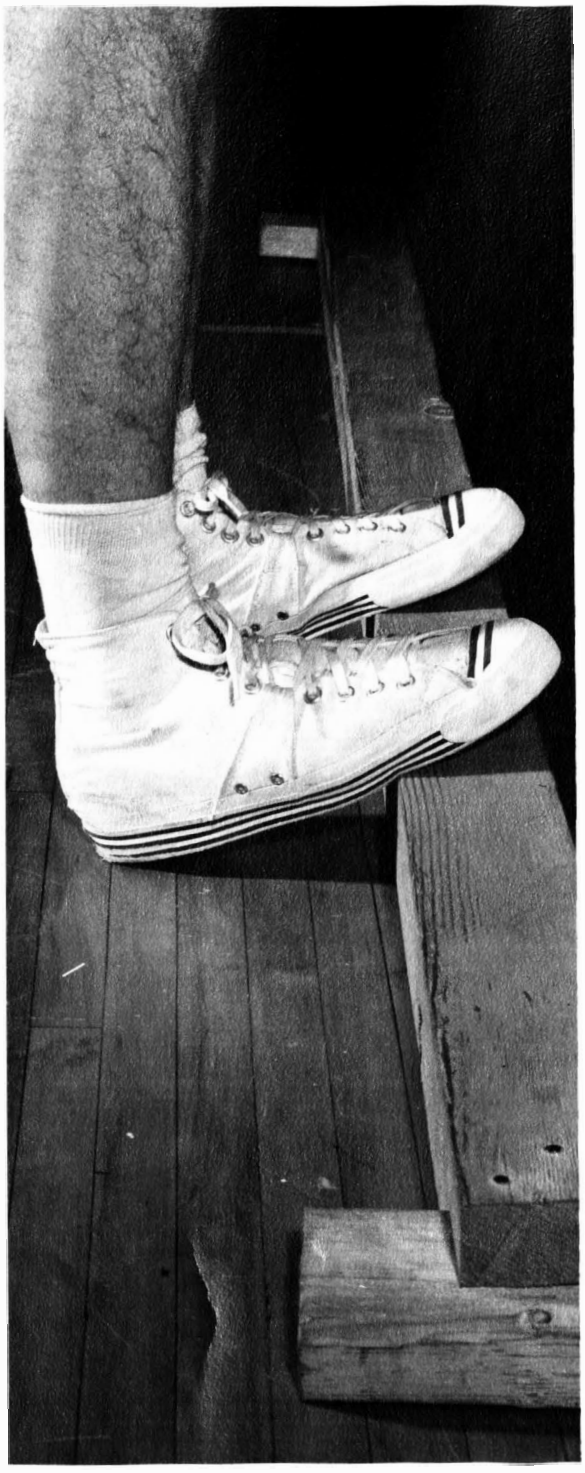

Figure 4. Heel Drop

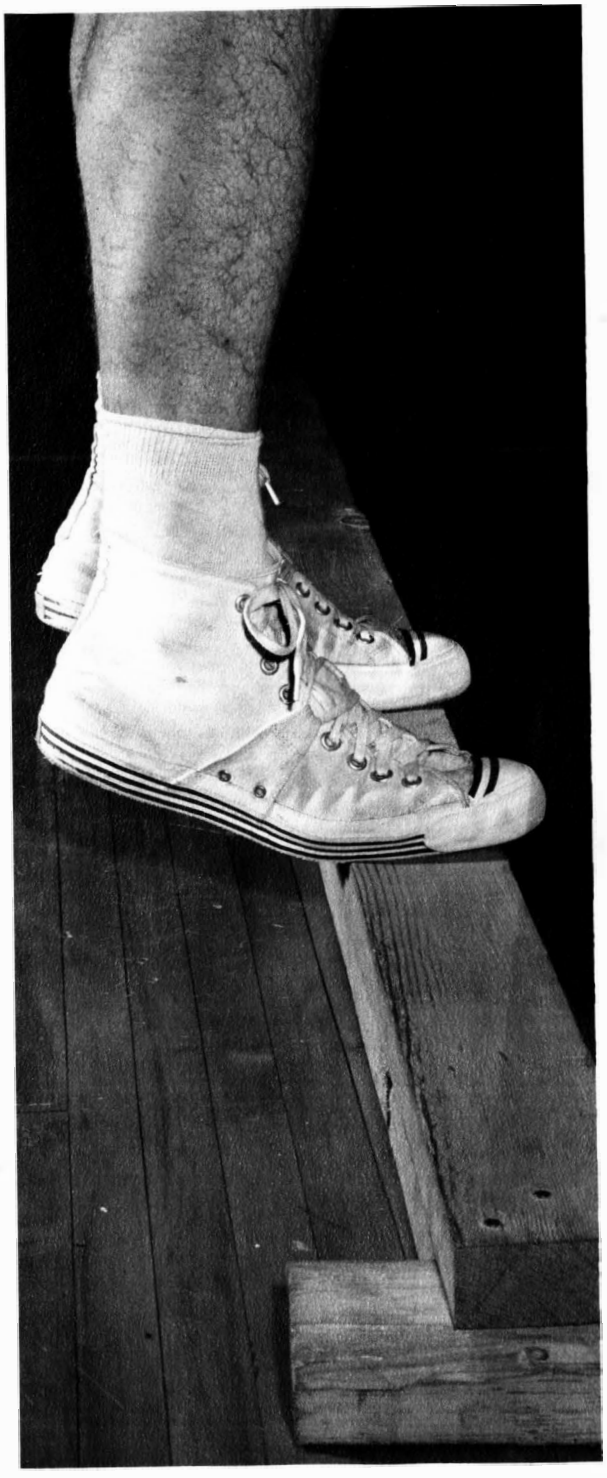

Figure 5. Toe Rise

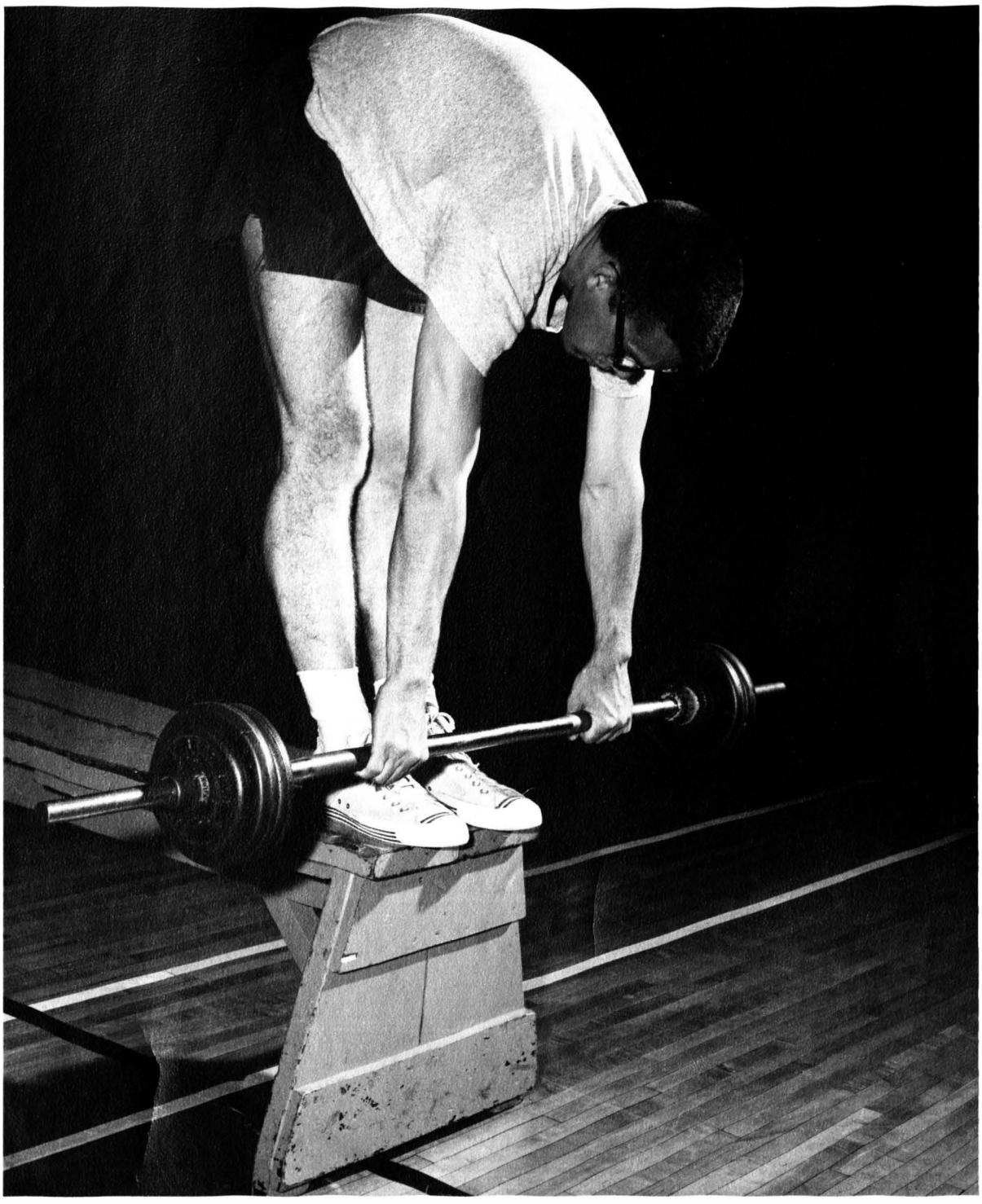

Figure 6. Dead Weight Bounce

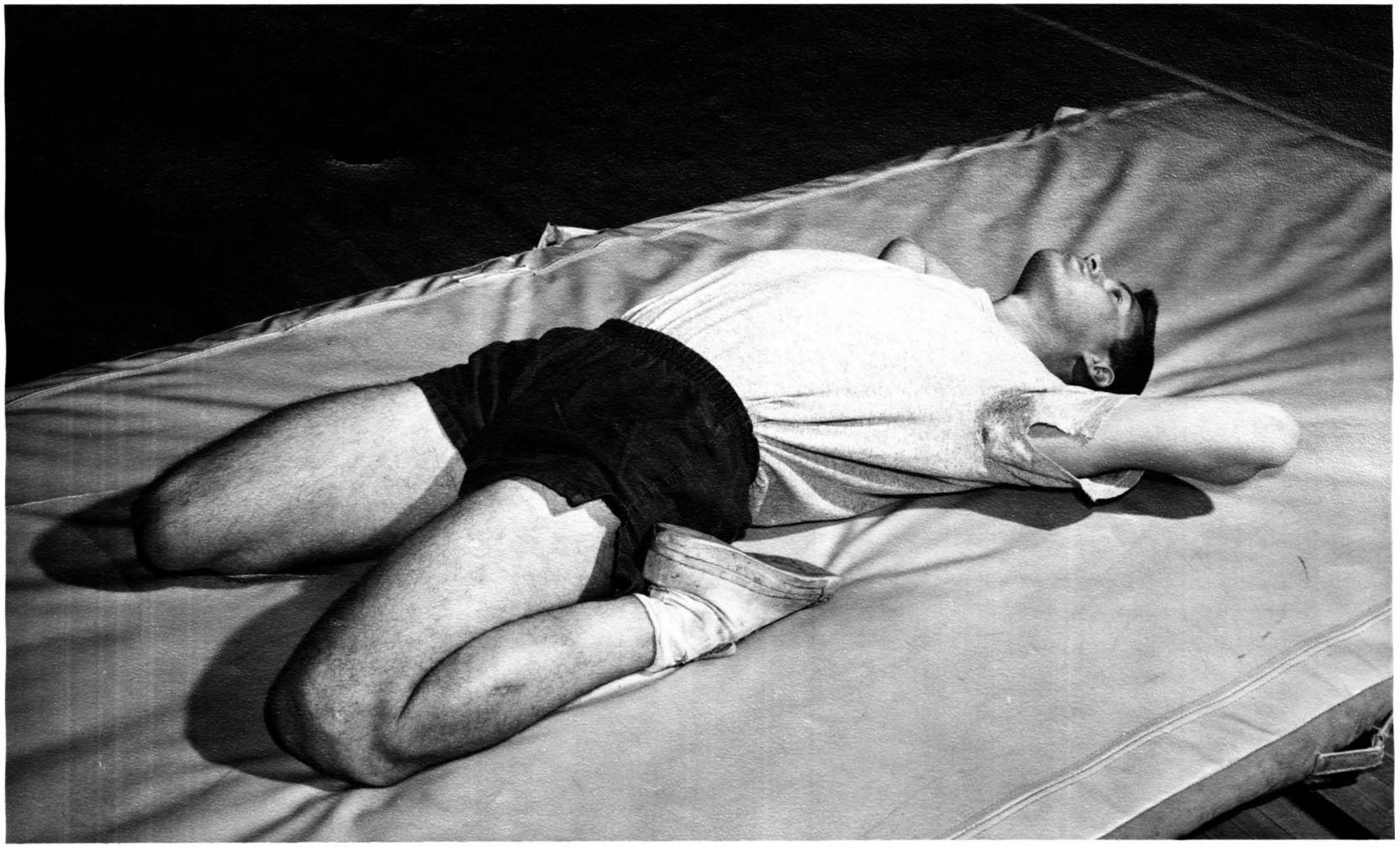

Figure 7. Back Bender

CHAPTER IV

TREATMENT AND ANALYSIS OF DATA

Treatment of Data

This investigation was carried out to determine the effect of a 6 ½ week program of weight lifting and flexibility exercises on free running speed. Three tests, leg strength, hip flexibility, and free running speed were administered to a control group and an experimental group before and after a 6 ½ week training period. The experimental design used was the equivalent pattern by which the mean scores and standard deviations from the mean of the control and experimental groups were equated in each test item after the initial test.

The means were derived for both the preliminary and final tests from the raw scores by means of the following formula.[32]

$$M = \frac{\Sigma X}{N}$$

The standard deviations from the mean were found by applying this formula.[33]

$$S.D. = \sqrt{\frac{\Sigma X^2}{N} - M^2}$$

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[32]Henry E. Garret, Statistics in Psychology and Education, p. 27, Longmans, Green and Company: New York, New York, 1958.

[33]Ibid., p. 53.

The results of the final test were tested against the null hypothesis, that the training program would show no real change in the scores of all three items tested. The preliminary and final tests in each item were correlated using the following formula.[34]

$$r = \frac{N\left[\Sigma X^2 + \Sigma Y^2 - \Sigma(X - Y)^2\right] - 2(\Sigma X)(\Sigma Y)}{2\sqrt{\left[N\Sigma X^2 - (\Sigma X)^2\right]\left[N\Sigma Y^2 - (\Sigma Y)^2\right]}}$$

The standard error of the difference of the means was derived from the following formula.[35]

$$SE_D = \sqrt{\left(\frac{SD_1}{N_1} + \frac{SD_2}{N_2}\right)(1 - r^2)}$$

The following formula was used to obtain the critical ratio or t value.[36]

$$t = \frac{\text{Diff.}}{SE_D}$$

Gain or loss was calculated for each subject in the experimental group in all three test items. The coefficients of correlation were derived to determine the relationship between change in leg strength and change in speed, and between change in hip flexibility and change in

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[34] Ibid., p. 146.

[35] Ibid., p. 230.

[36] Ibid., p. 215.

speed. The following formula was used.[37]

$$r = \frac{\frac{x'y'}{N} - c_x c_y}{(SD'_x)(SD'_y)}$$

Analysis of Data

The degrees of significance were found in table D of Garrett.[38] At 68 degrees of freedom $(N - 1)+(N - 1)$, a t value of 2.00 or more was statistically significant at the .05 level and a t value of 2.66 or more was statistically significant at the .01 level. The five per cent level of significance was accepted for this study.

TABLE I. MEAN, STANDARD DEVIATION OF THE MEAN, AND DIFFERENCES BETWEEN THE MEANS COMPUTED FROM THE LEG STRENGTH, HIP FLEXIBILITY, AND SPEED OF RUNNING TESTS OF THE CONTROL GROUP

	N	Preliminary Test M_1	Preliminary Test SD_1	Final Test M_2	Final Test SD_2	Diff.
Leg Strength	35	543.00	121.17	541.00	117.70	-2.00
Hip Flexibility	35	116.94	10.689	120.07	10.523	+3.13
Speed of Running	35	2.3638	.1237	2.3083	.0916	-.0600

[37] Ibid., p. 138.

[38] Ibid., p. 449.

Table I shows the mean difference in scores for all test items in the control group. Gains were recorded in hip flexibility and speed of running while a slight loss occurred in the mean leg strength score.

TABLE II. MEAN, STANDARD DEVIATION OF THE MEAN, AND DIFFERENCES BETWEEN THE MEANS COMPUTED FROM THE LEG STRENGTH, HIP FLEXIBILITY, AND SPEED OF RUNNING TESTS OF THE EXPERIMENTAL GROUP

	N	Preliminary Test M_1	Preliminary Test SD_1	Final Test M_2	Final Test SD_2	Diff.
Leg Strength	35	545.29	128.98	604.57	150.80	+59.28
Hip Flexibility	35	115.34	8.0165	122.94	6.198	+7.60
Speed of Running	35	2.3531	.1257	2.2697	.1098	-.0834

Table II shows the mean difference in scores for the test items in the experimental group. Improvement occurred in every area.

TABLE III. MEAN SCORES OF FINAL TESTS, DIFFERENCES BETWEEN MEAN SCORES, COEFFICIENTS OF CORRELATION BETWEEN PRELIMINARY AND FINAL TESTS, STANDARD ERRORS OF THE DIFFERENCES BETWEEN THE MEANS, T-VALUES, AND LEVELS OF SIGNIFICANCE IN LEG STRENGTH, HIP FLEXIBILITY, AND SPEED OF RUNNING

	Control M_2	Exp. M_2	Diff.	r	SE_D	t	Sig.
Leg Strength	541.00	604.57	63.57	.7221	22.37	2.842	.01
Hip Flexibility	120.07	122.94	2.872	.5263	1.810	1.5867	none
Speed of Running	2.3083	2.2697	.0386	.8256	.0139	2.7730	.01

Table III shows the mean differences of the final tests and levels of significance of these differences. The mean gain in leg strength of 63.57 pounds was significant at the .01 level, and the mean gain of the experimental group over the control group in speed of .0386 seconds was also significant to the .01 level. Therefore, the null hypothesis was rejected in both cases and the gains in leg strength and speed were accepted as real. The mean gain in hip flexibility of the experimental group over the control group of 2.87 degrees was not significant and the null hypothesis was accepted.

The coefficients of correlation were found to determine if improved leg strength was associated with improved speed, and if improved hip flexibility was associated with improved speed. Change in leg strength was found to correlate -.24 with change in speed, while change in hip flexibility showed a slight positive correlation with change in speed of .33.

Improvement was found in both groups on all test items except leg strength. On this item, the control group showed a slight loss. The null hypothesis was rejected and the differences found to be real for both the leg strength and speed of running tests. Even though a greater gain in hip flexibility was experienced by the experimental group, it was not a significant gain and the gain cannot be said to be real. There was a slight negative correlation of change in leg strength to change in running speed, and a slight positive correlation of change in hip flexibility to change in running speed.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

This study was undertaken to determine the effects of a 6 ½ week weight training and flexibility exercise program on free running speed. An experimental group of 35 freshman men at South Dakota State College participated in the training program during the winter of 1961. A control group of the same number participated in volleyball and basketball classes during the experiment. Tests of leg strength, hip flexibility, and free running speed for 20 yards were administered to both groups prior to and following the training program. The groups were equated by means and standard deviations from the mean on all three test items as found in the preliminary tests.

Increased leg strength and free running speed in the experimental group were found to be significant at the .01 level. Both groups improved in hip flexibility, but the difference in gain of the experimental group over the control group was not significant. Coefficients of correlation were taken on the changes in leg strength and hip flexibility as related to the changes in running speed of the experimental group. A slight positive correlation of .33 was found between improved hip flexibility and improved speed of running. There was a negative relationship between improved leg strength and improved speed.

Conclusions

1. The 6 ½ week program of progressive resistance weight training and flexibility exercises increased leg strength, as measured by the Medart-Chatillon back and leg dynamometer without the belt, more than a similar period of volleyball and basketball.

2. The 6 ½ week program of progressive resistance weight training and flexibility exercises increased free running speed over a distance of 20 yards more than a similar period of volleyball and basketball.

3. Increased leg strength appears to have a slight slowing effect on free running speed.

4. It was indicated that increased hip flexibility seemed to have a positive effect on free running speed.

Recommendations

1. A similar study with more subjects and a longer training period should be undertaken.

2. Additional studies should be made of the relationship of flexibility to running speed.

3. A similar study should be made using members of varsity track teams in order that the factor of proper mechanical running form be included.

4. Off-season conditioning programs for runners should include a combination of weight training and flexibility exercises.

5. A similar study using three experimental groups; a weight

training group, a flexibility exercise group, and a combination group should be undertaken.

6. A study should be undertaken comparing a program of heavy resistive exercises and a program of light resistive exercises emphasizing speed and their effect on leg strength and free running speed.

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APPENDICES

APPENDIX A

DESCRIPTION OF TESTING PROCEDURES

All subjects were clothed in a physical education outfit consisting of T-shirt and trunks for all tests.

Leg Strength

Equipment: Medart-Chatillon back and leg dynamometer, foot stool, chain, and handle.

Instructions:
1. Subject stands on stool with feet placed six inches apart and the center of the foot opposite the chain. Subject holds bar with both hands near the chain. The bar should rest at the bend between the trunk and the thighs.
2. Bend the legs at the knees so that a 115 to 124 degree angle is created. Attach the chain.
3. Keeping arms straight, back straight, head and chest up, pull with legs until they are nearly straight.

Recording: Two tests were administered and the highest score recorded to the nearest five pounds. A third test was administered if there existed a large discrepency between the first two, and the highest of the two close scores was recorded.

Right Hip Flexibility

Equipment: Leighton flexometer.

Instructions:
1. Subject lying on back. Attach flexometer to right thigh, six inches above the patella. With face of instrument perpendicular to the floor, allow both pointer and dial to settle at zero degrees. Lock dial.
2. With attendant holding subject's left knee, subject brings right knee up as far into his chest as possible. Lock pointer. (Subject is allowed to bend at knee and the movement is performed slowly and evenly, so that the pointer will quickly become stationary.)

Recording: Two tests were read to the nearest degree. If a marked discrepency occurred, a third test was administered. The average of the two close scores was recorded.

Speed of Running

Equipment: Rubber mat runway, two switch mats placed at the 20 and 40 yard marks, Hale reaction-performance timer, and extension cord.

Instructions:
1. Subject was allowed one practice run in order to become adjusted to the switch mat placement. He began run 20 yards before first switch mat. Run was timed for the 20 yards between mat #1 and mat #2 (Figure 1).
2. Subject was instructed to begin running at maximum speed and not to concentrate on making foot contact with mats as additional trials would be given.
3. Time for each trial was marked down and announced to the subject. (It was felt that the subject would attempt to compete against his own first mark if it was reported to him.)

Recording: A minimum of two successful (hitting both mats) trials were given. A maximum of four trials was allowed to anyone who felt he could improve his time. The fastest time for the 20 yards distance was recorded.

APPENDIX B

DESCRIPTION OF TRAINING PROGRAM

Adding Weight

Subject was instructed to begin lifting a weight that he personally believed he could handle. As soon as he was able to complete the required number of sets and repetitions, he had to add a minimum of 10 pounds to the barbell. (This minimum was 2 ½ pounds for the boot lift.) There was no maximum weight addition, so many subjects added as much as 30 pounds after the initial lifting period. Each subject kept a personal daily record of his progress.

Shoulder Press

Description: Starting position - standing, barbell just in front of shoulders, palms forward.
Exercise - thrust barbell upward to arm's length over the head. Inhale from top down, hold it, exhale at top.

Repetitions: Do five sets of five repetitions.

Weight used: starting weight; range - 40 to 75 lbs., ave. - 63.9 lbs.
final weight; range - 75 to 115 lbs., ave. - 95.6 lbs.

Arm Curl

Description: Starting position - standing, barbell in front of thighs, palms forward.
Exercise - flex forearms completely until barbell is just in front of shoulders. Inhale up, and exhale down.

Repetitions: Do two sets of 10 repetitions.

Weight used: starting weight; range - 50 to 65 lbs., ave. - 58.4 lbs.
final weight; range - 75 to 100 lbs., ave. - 82.3 lbs.

Boot Lift

Description: Starting position - with boot attached to right foot, stand with left foot on bench.
Exercise - lift leg until thigh is parallel to the ground. Hands may be held against the wall for balance. Normal breathing.

Repetitions: Do one set of 10 repetitions. Repeat with left foot.

Weight used: starting weight; range - 12 ½ to 25 lbs., ave. - 13.9 lbs.
final weight; range - 30 to 52 ½ lbs., ave. - 43.6 lbs.

Semi-squat Walks

Description: Starting position - subject standing with barbell behind neck.
Exercise - take a step about 1 ½ feet in length forward with one foot and then squat down on the rear heel until the thigh of the forward leg is parallel with the floor. Upon rising, stride forward with the opposite foot. Repeat and continue the movement. Breath naturally.

Repetitions: Do a total of 30 steps.

Weight used: starting weight; range - 50 to 95 lbs., ave. - 78.0 lbs.
final weight; range - 125 to 220 lbs., ave. - 183.4 lbs.

Toe Rise

Description: Starting position - barbell resting on shoulders behind neck. Stand with balls of feet on four inch board.
Exercise - rise on toes. Breath naturally.

Repetitions: Do three sets of 15 repetitions. (One set each with toes pointing in, straight, and out.)

Weight used: starting weight; range - 55 to 75 lbs., ave. - 72.3 lbs.
final weight; range - 105 to 200 lbs., ave. - 134.4 lbs.

Heel Drop

Description: Used in conjunction with the toe rise exercise. As heels return to the ground, keep knees locked.

Repetitions: Do three sets of 15 repetitions.

Weight used: Same as for toe rise exercise.

Dead Weight Bounce

Description: Starting position - standing on bench, hold barbell against thighs at arm's length, palms in.
Exercise - bend forward as far as possible while maintaining balance. Bounce slightly 10 times and try to reach lower each time.

Repetitions: Repeat this three times.

Weight used: Same for all. Began at 45 lbs., added 10 lbs. at the end of every four sessions to a final weight of 75 lbs.

Back Bender

Description: Starting position - kneel on ground and sit back on heels.
Exercise - lean backwards as far as possible, and return to starting position.

Repetitions: Repeat this 10 times.

APPENDIX C

RAW SCORES OF PRELIMINARY AND FINAL TESTS

Control Group

Subject	Leg Strength X_1	Leg Strength X_2	Hip Flexibility X_1	Hip Flexibility X_2	Speed of Running X_1	Speed of Running X_2
#1	430	460	92.0	119.0	2.56	2.26
#2	560	600	93.5	129.5	2.25	2.16
#3	790	780	120.5	131.0	2.26	2.13
#4	410	410	112.0	109.0	2.14	2.12
#5	440	410	102.0	114.5	2.42	2.38
#6	550	570	125.0	128.0	2.50	2.34
#7	600	480	119.5	121.0	2.39	2.35
#8	440	525	124.5	121.0	2.40	2.36
#9	630	620	120.5	114.0	2.56	2.47
#10	610	600	118.0	120.0	2.39	2.34
#11	345	340	110.0	88.0	2.25	2.21
#12	620	730	125.0	125.0	2.56	2.40
#13	560	530	129.0	116.0	2.37	2.28
#14	680	630	100.5	108.0	2.60	2.45
#15	520	540	106.5	104.0	2.47	2.41
#16	660	560	122.0	126.5	2.23	2.26
#17	600	600	108.0	125.5	2.39	2.31
#18	560	540	117.5	123.0	2.39	2.32

Subject	Leg Strength X_1	Leg Strength X_2	Hip Flexibility X_1	Hip Flexibility X_2	Speed of Running X_1	Speed of Running X_2
#19	820	880	109.5	107.0	2.39	2.31
#20	630	560	128.0	127.5	2.26	2.28
#21	480	580	126.5	131.5	2.50	2.46
#22	330	380	115.0	114.5	2.14	2.16
#23	560	610	122.0	126.0	2.41	2.34
#24	480	510	134.0	136.0	2.35	2.28
#25	400	440	108.5	111.0	2.50	2.42
#26	530	410	119.5	114.5	2.44	2.39
#27	520	580	119.0	118.5	2.35	2.32
#28	570	550	121.5	128.5	2.41	2.41
#29	350	380	107.0	108.0	2.20	2.21
#30	410	360	111.0	126.0	2.30	2.37
#31	800	590	122.5	124.5	2.13	2.13
#32	570	550	126.5	119.5	2.48	2.41
#33	510	620	135.0	136.0	2.31	2.23
#34	420	420	107.0	114.0	2.33	2.24
#35	620	590	134.5	141.5	2.25	2.28

Experimental Group

Subject	Leg Strength X_1	Leg Strength X_2	Hip Flexibility X_1	Hip Flexibility X_2	Speed of Running X_1	Speed of Running X_2
#1	390	540	114.0	118.0	2.56	2.30
#2	420	590	107.5	120.5	2.50	2.38
#3	480	520	101.5	117.0	2.55	2.45
#4	525	540	108.5	119.0	2.37	2.21
#5	735	760	113.0	116.5	2.48	2.30
#6	590	650	112.0	115.5	2.44	2.28
#7	660	860	111.5	120.0	2.27	2.31
#8	700	660	123.5	136.5	2.34	2.26
#9	400	590	106.0	131.0	2.27	2.12
#10	600	570	107.0	120.5	2.58	2.37
#11	310	430	118.5	117.0	2.27	2.17
#12	610	690	116.5	125.0	2.17	2.14
#13	360	410	116.5	132.0	2.46	2.36
#14	595	690	120.0	126.0	2.39	2.27
#15	650	720	111.0	119.5	2.21	2.04
#16	680	630	114.5	123.5	2.49	2.35
#17	600	620	124.0	135.5	2.41	2.30
#18	200	450	113.5	118.0	2.59	2.50
#19	320	790	131.0	139.0	2.30	2.29
#20	625	580	114.5	118.0	2.15	2.09
#21	570	840	129.5	128.5	2.29	2.29

Subject	Leg Strength X_1	X_2	Hip Flexibility X_1	X_2	Speed of Running X_1	X_2
#22	650	590	107.0	121.0	2.26	2.19
#23	380	450	117.0	120.5	2.41	2.36
#24	500	620	117.5	122.0	2.16	2.13
#25	625	610	109.5	119.5	2.31	2.31
#26	770	830	114.5	119.5	2.19	2.18
#27	575	640	106.5	108.5	2.29	2.23
#28	635	620	139.0	130.5	2.33	2.34
#29	590	730	118.0	117.0	2.42	2.37
#30	510	560	113.0	113.0	2.25	2.14
#31	520	620	128.5	132.0	2.30	2.35
#32	685	670	105.5	130.0	2.14	2.08
#33	540	540	113.0	128.0	2.39	2.20
#34	500	520	116.0	124.0	2.42	2.37
#35	585	570	118.0	121.0	2.40	2.41